

# ITER edge plasmas modeling:\*

- (a) single-null fluid Be, Sn(W);
- (b) neutral CX-wall flux;
- (c) 2<sup>nd</sup> X-pt hydrogen SOL

**T.D. Rognlien, R.H. Bulmer, and M.E. Rensink**

Lawrence Livermore National Laboratory

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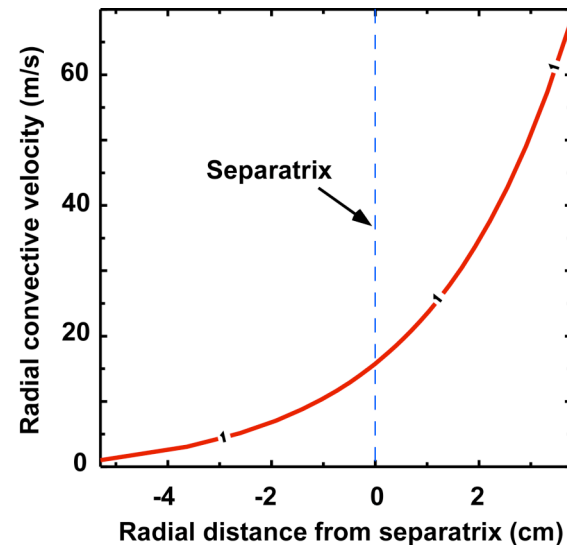
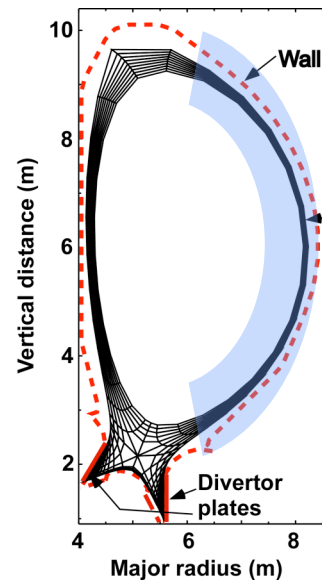
\* Work performed under the auspices of U.S. DOE by the Univ. of Calif. Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

# Previous ITER divertor-plasma modeling assumed diffusive radial transport only; we add convection



- ITER assumes 100 MW power input to SOL
- Here carbon modeled as a 3% concentration
- Anomalous radial diffusion set at  $D = 0.3 \text{ m}^2/\text{s}$ ,  $\chi_{e,i} = 1 \text{ m}^2/\text{s}$
- We add a radial convection term on outboard side, as experiments and simulations imply

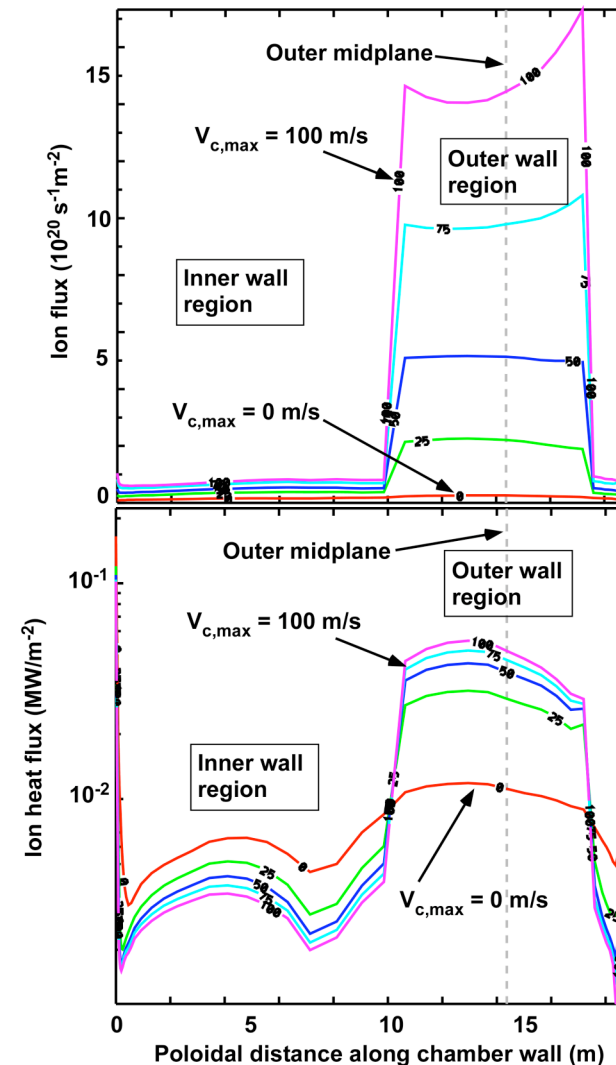
$$\text{radial particle-flux } \Gamma_n = -D \frac{dn}{dr} + V_{\text{conv}} n$$



# Plasma fluxes to the wall increase more than local density owing to ionization of recycled gas



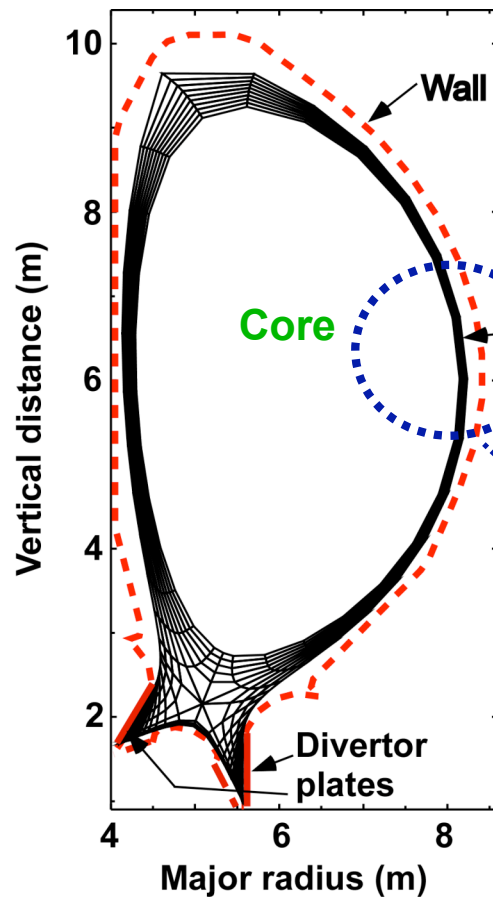
- Since  $n_i$  and  $V_{\text{conv}}$  increase, the  $nV$  flux is much larger
- Ionized neutrals contribute the flux
- Ion temperature decreases some owing to cold ionization source; ion energy flux slower
- Hot cx-neutrals, sheath drop to be added to energy flux



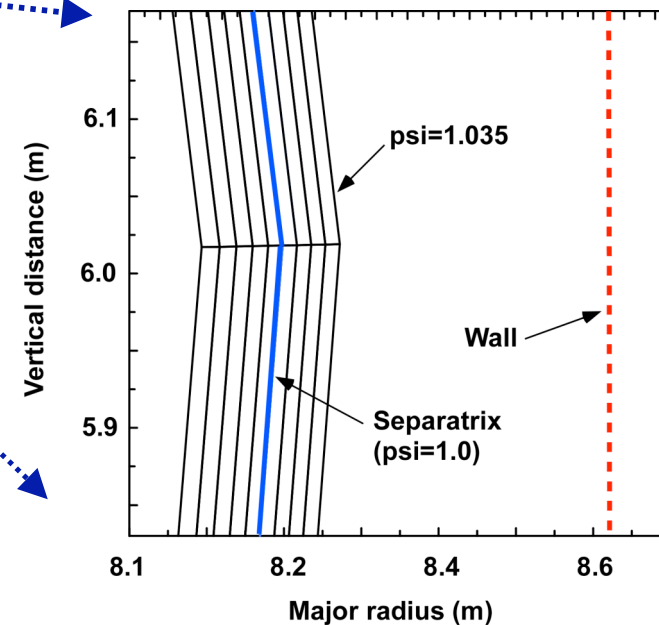
# ITER utilizes a single-null divertor with steeply-inclined divertor plates



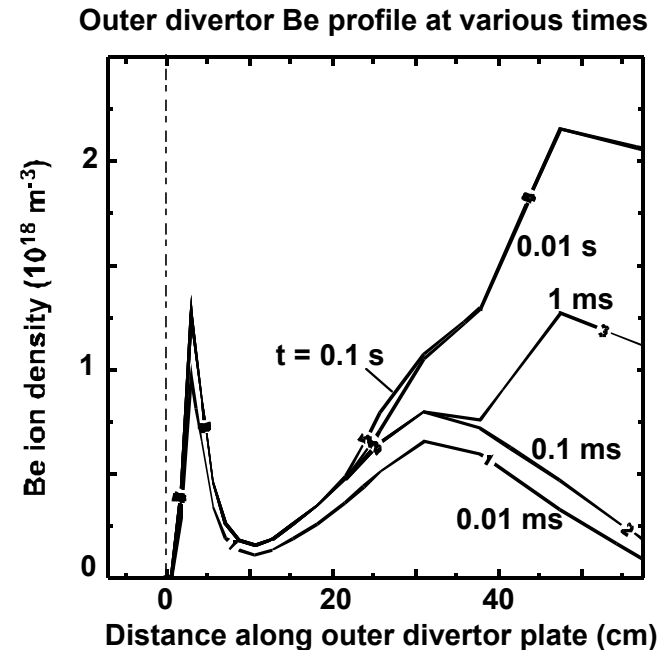
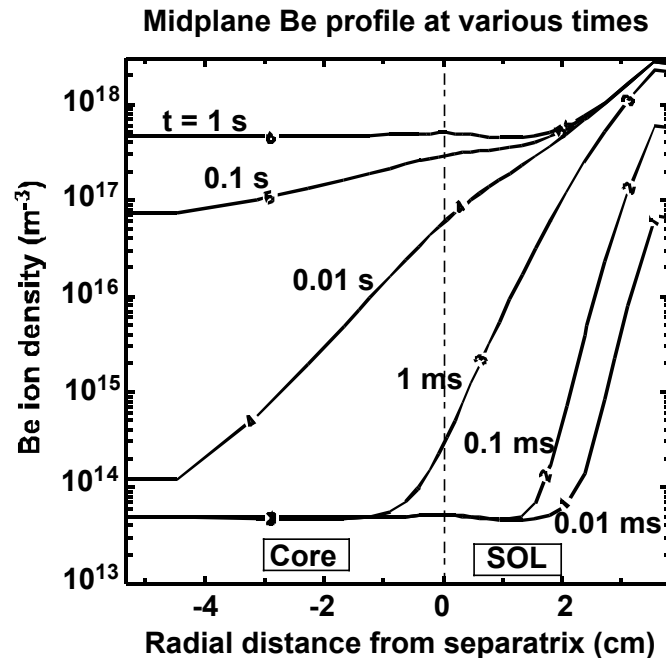
Poloidal cross-section showing edge-plasma region



- Nearly vertical plates reduce heat flux & facilitate plasma detachment
- Carbon radiation helps reduce  $T_e$  near strike point to allow He pumping



# Be physical sputtering yields acceptable core concentration for $V_{y\text{conv-max}} = 70 \text{ m/s}$ at wall

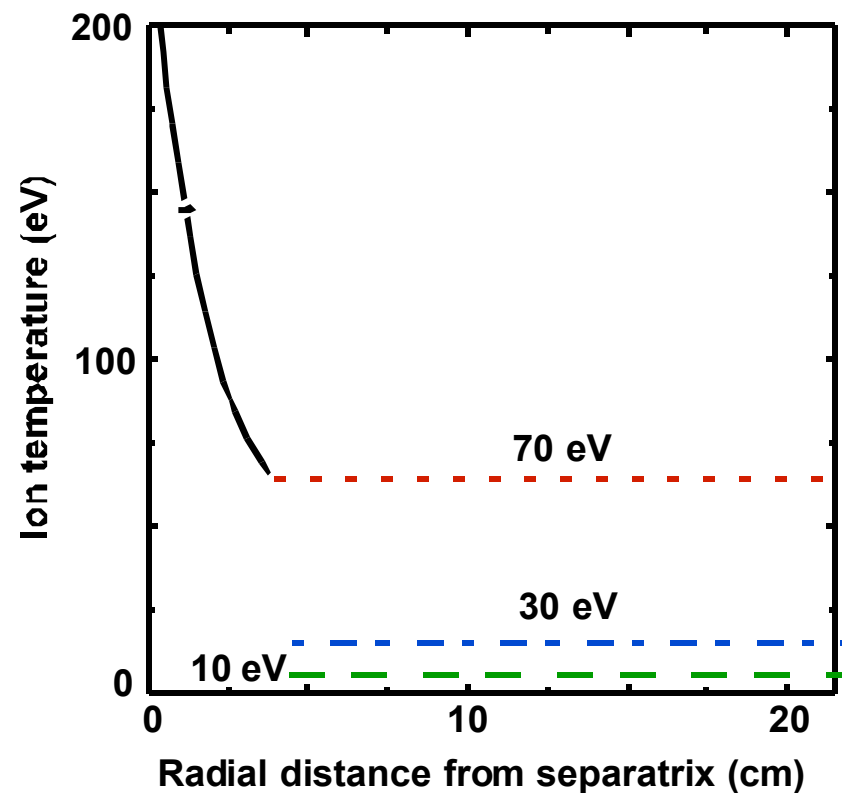
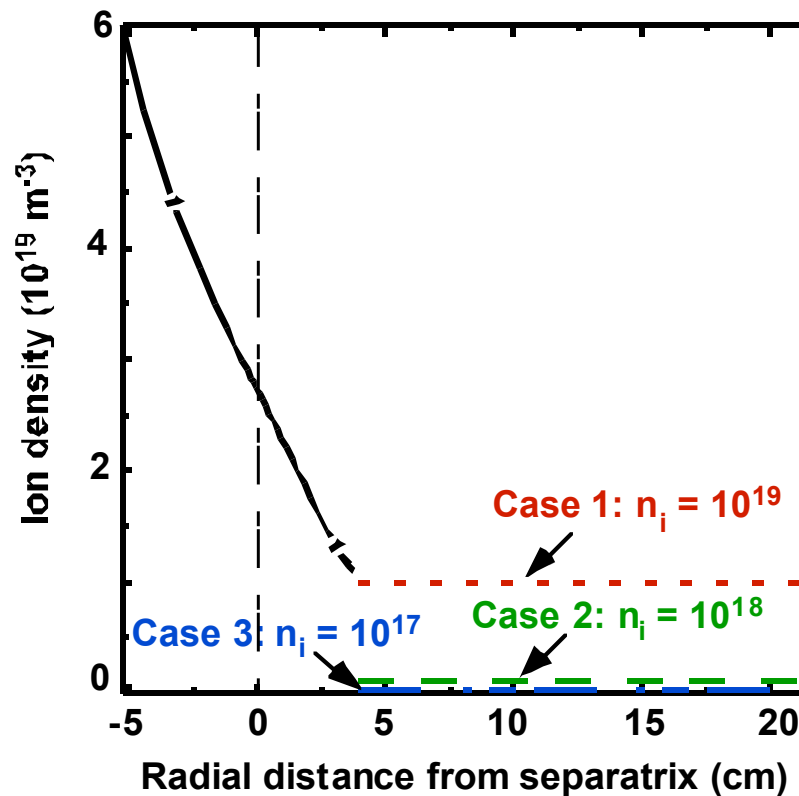


- Roughly consistent with WBC, but shows separatrix structure (should understand this better)
- About 1% Be concentration at core edge; tolerable, but non-trivial with long timescale for steady-state
- Convection level is uncertain, so Be estimates are also

# Charge-exchange hydrogen can present a substantial sputtering source at the wall



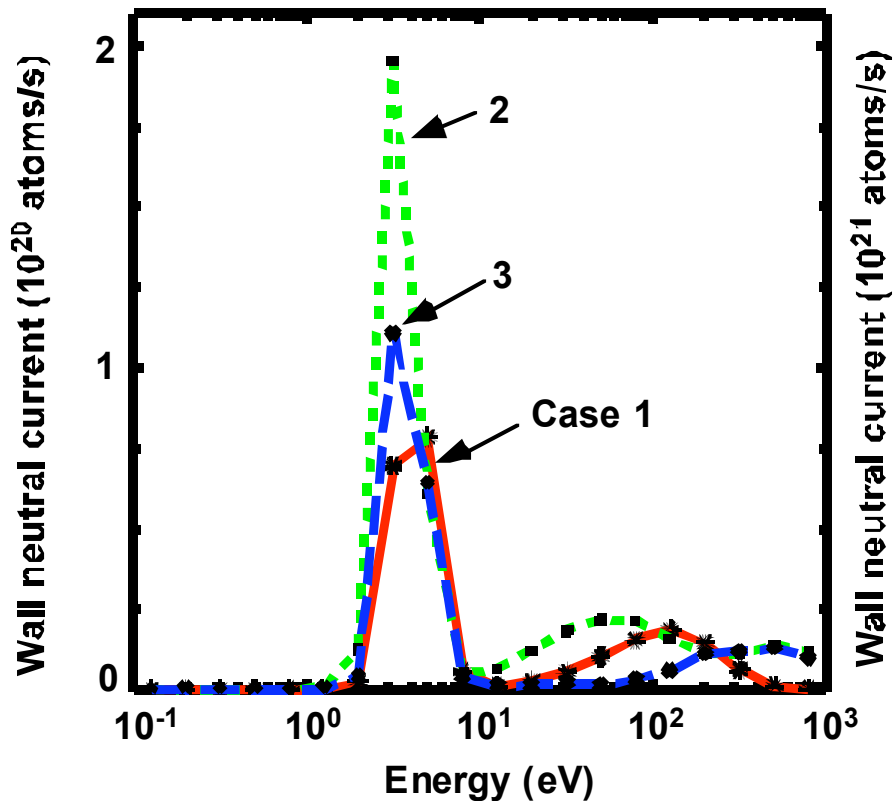
Plasma for  $r < 3.7$  cm from UEDGE  
case ffC.6 with convective transport;  
plasma for  $r > 3.7$  cm for 3 models



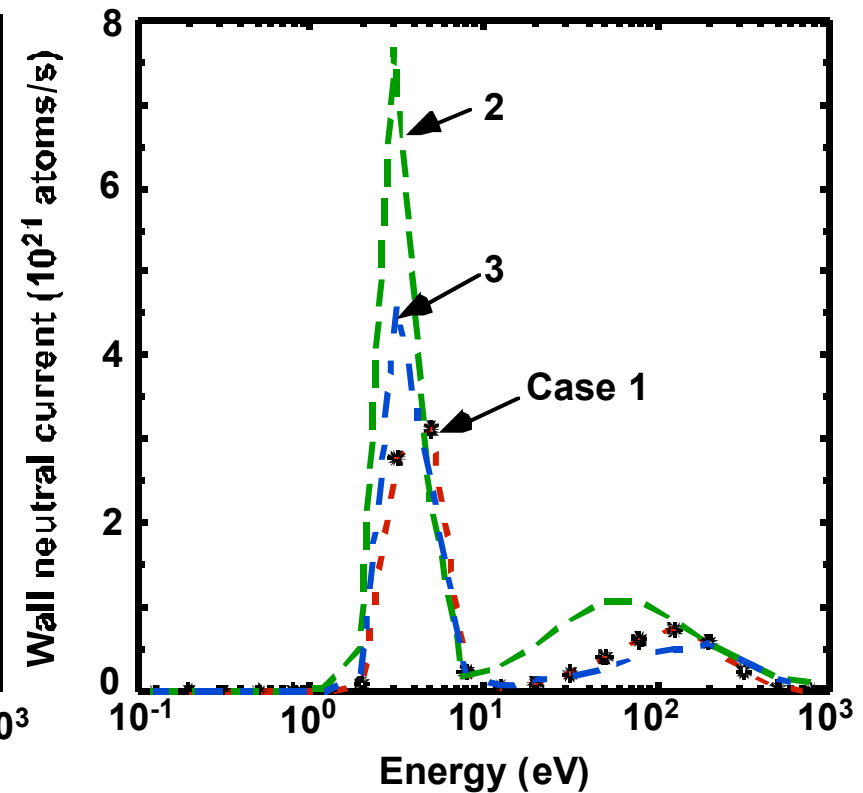
# DEGAS 2 is used to calculate the energy spectrum of hydrogen neutrals incident on the wall



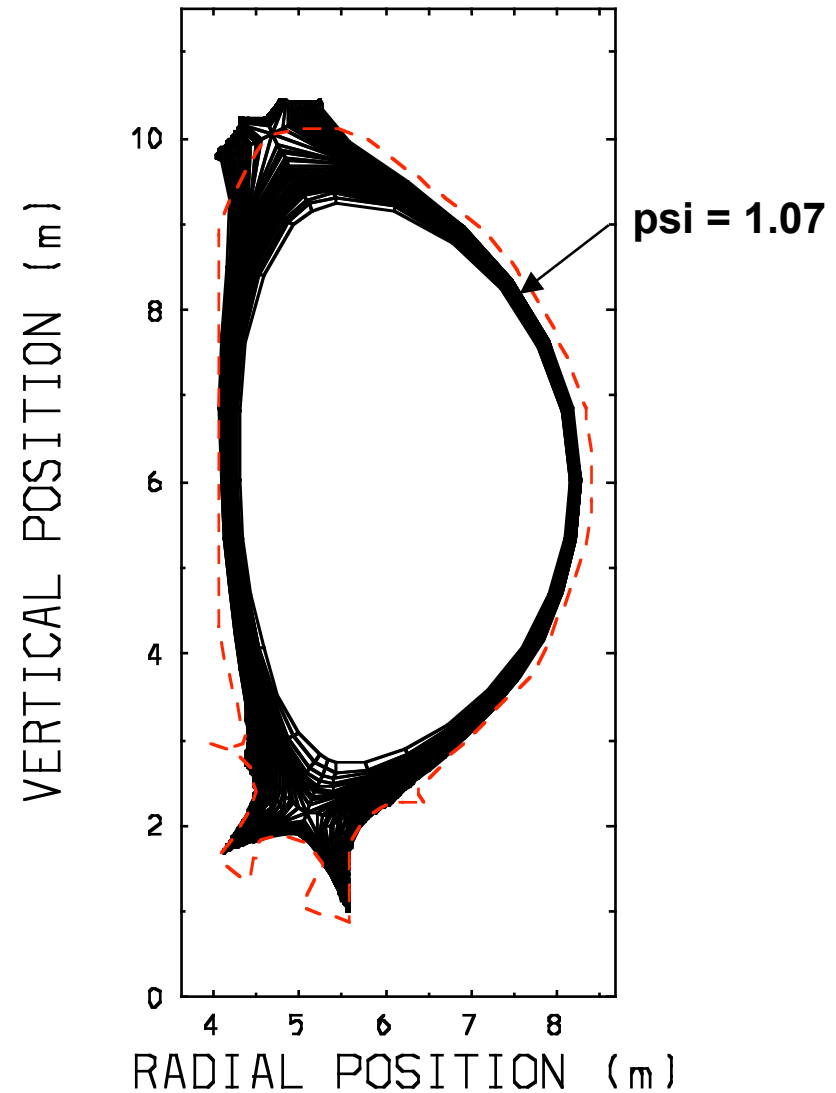
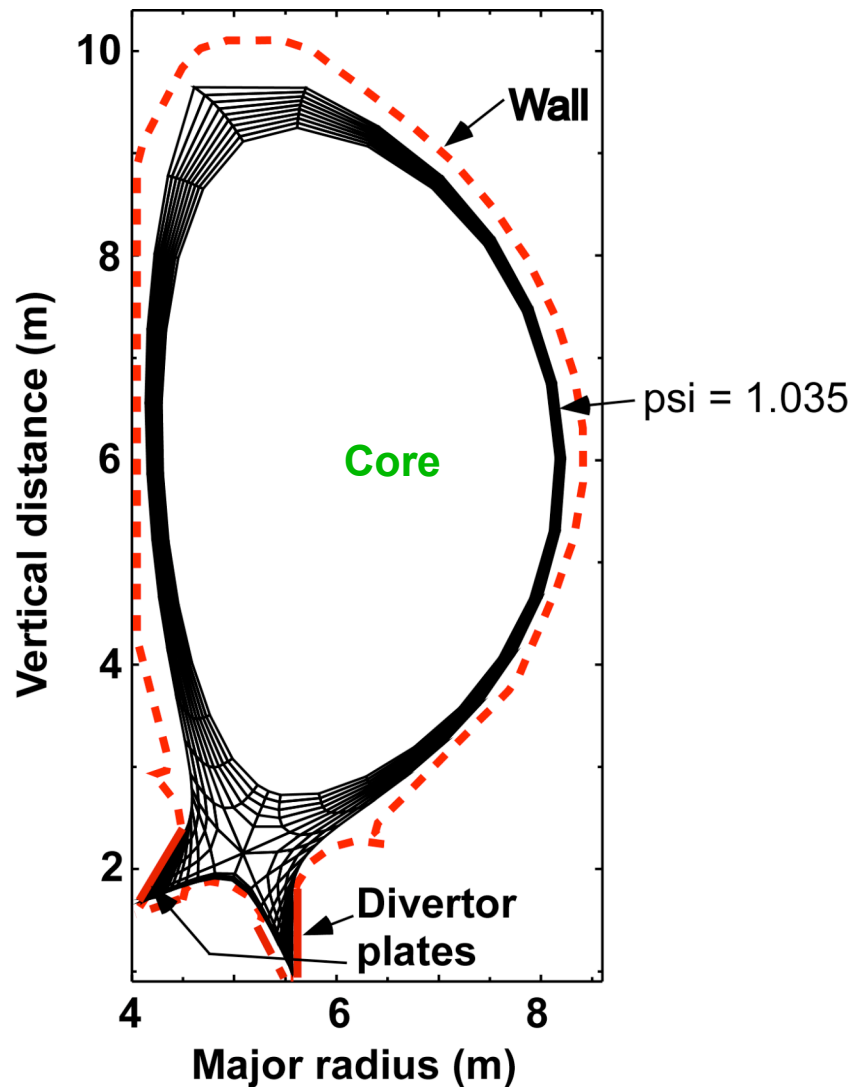
No convection (note scale)



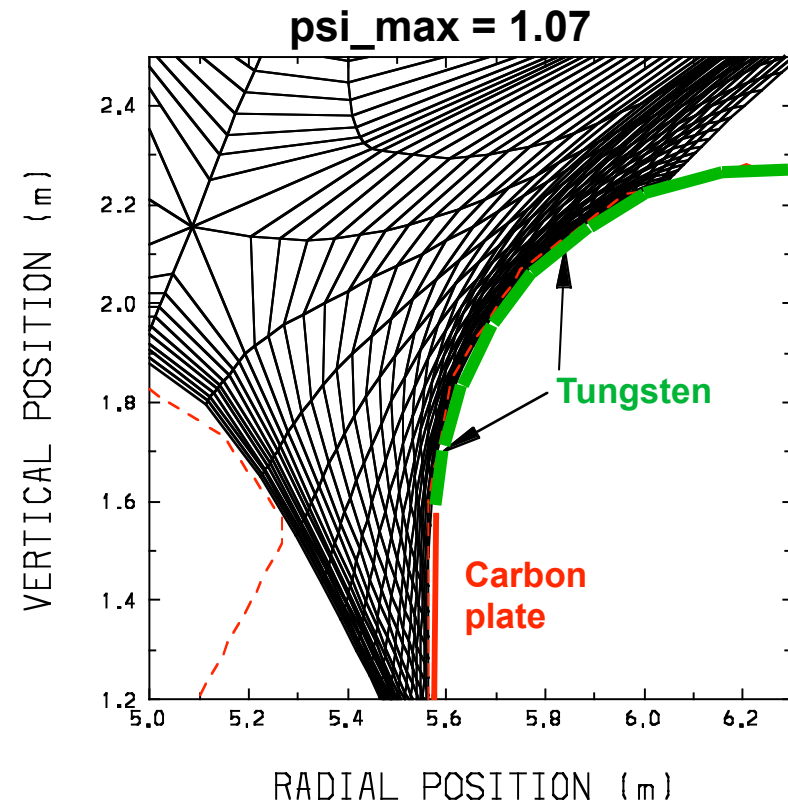
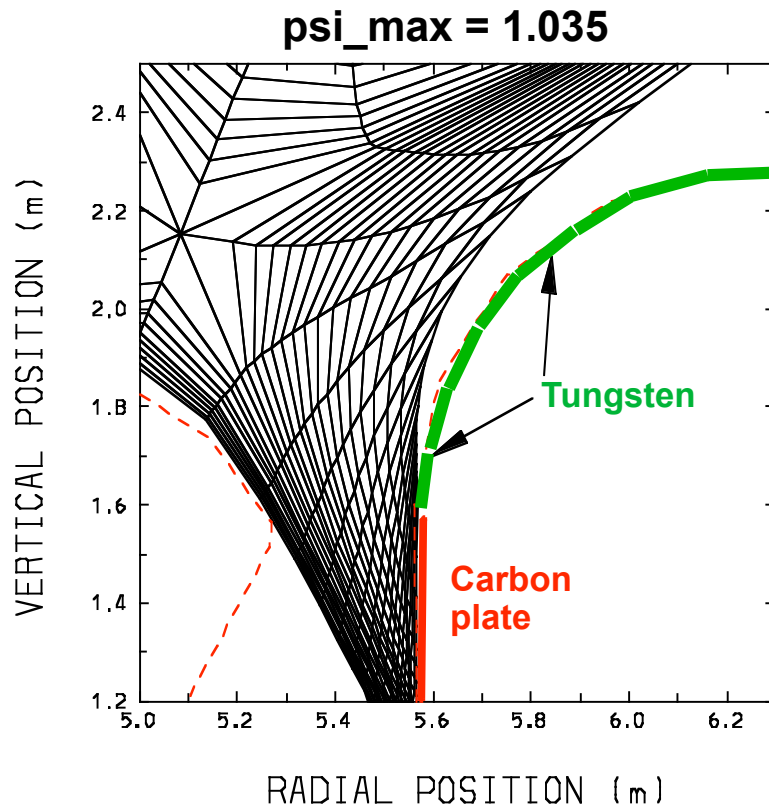
With convection (note scale)



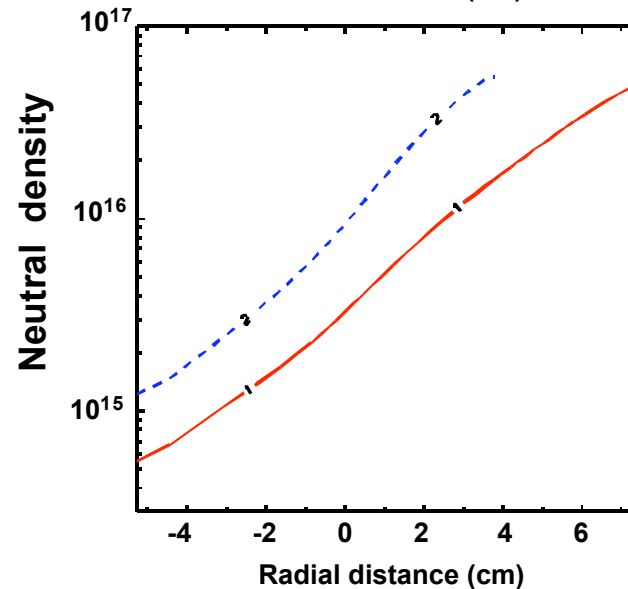
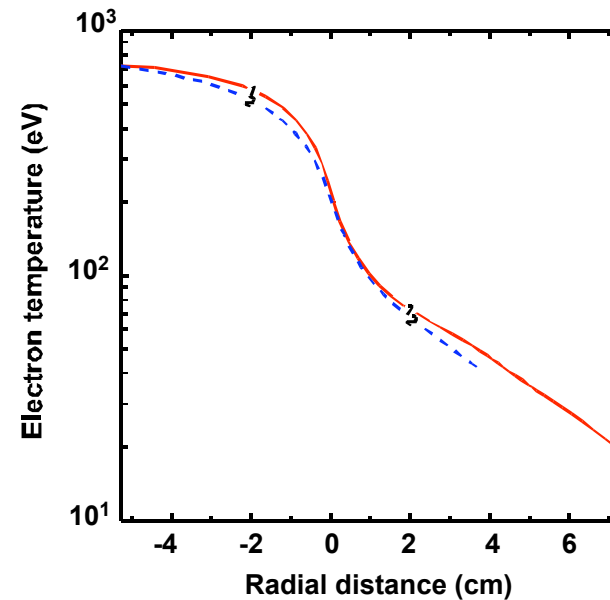
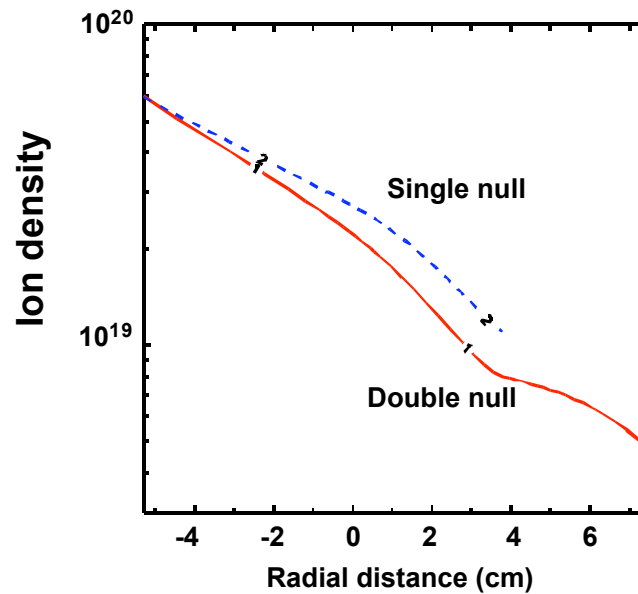
We have doubled the size of the SOL, which brings in the upper X-point & 2 separatrices



# We can now consistently treat the SOL plasma striking the W baffle



# Midplane $n_i$ and $n_g$ are most strongly affected by the expanded SOL; less main wall recycling

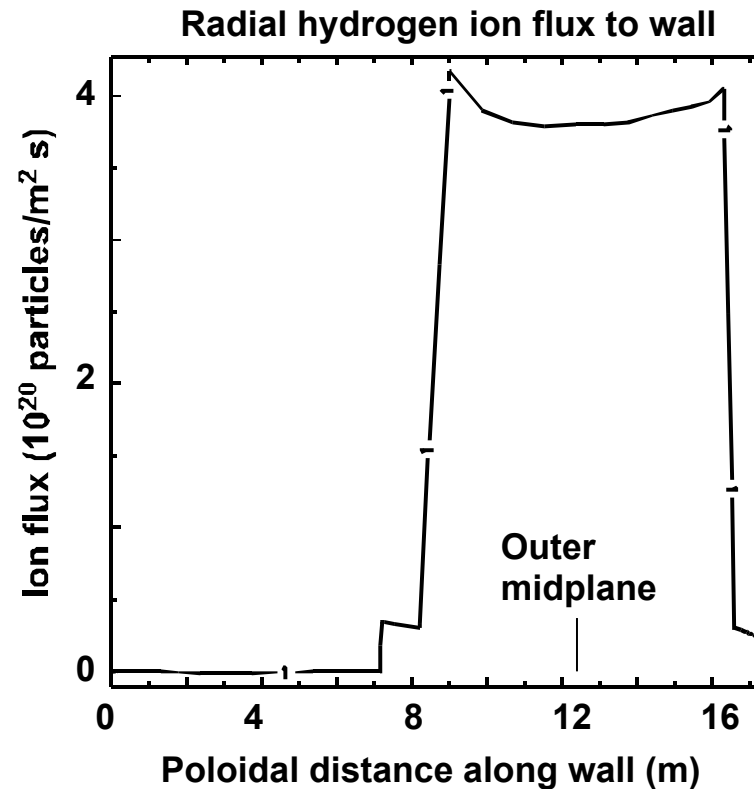
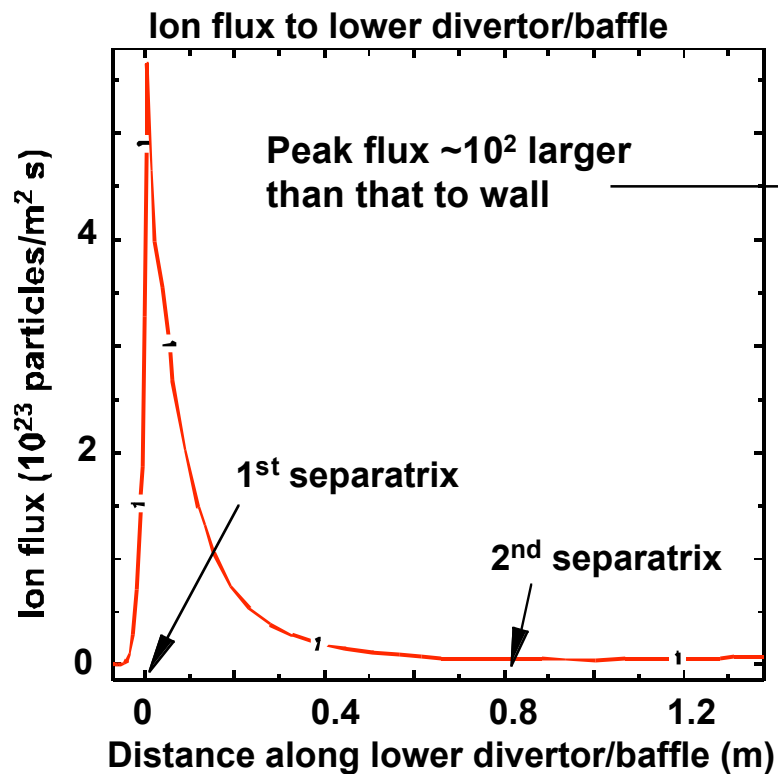


- Substantial effort to improve UEDGE to work for these cases
- Convergence to steady-state now appears routine

# Hydrogen particle flux is much larger to the divertor than the walls, but ...



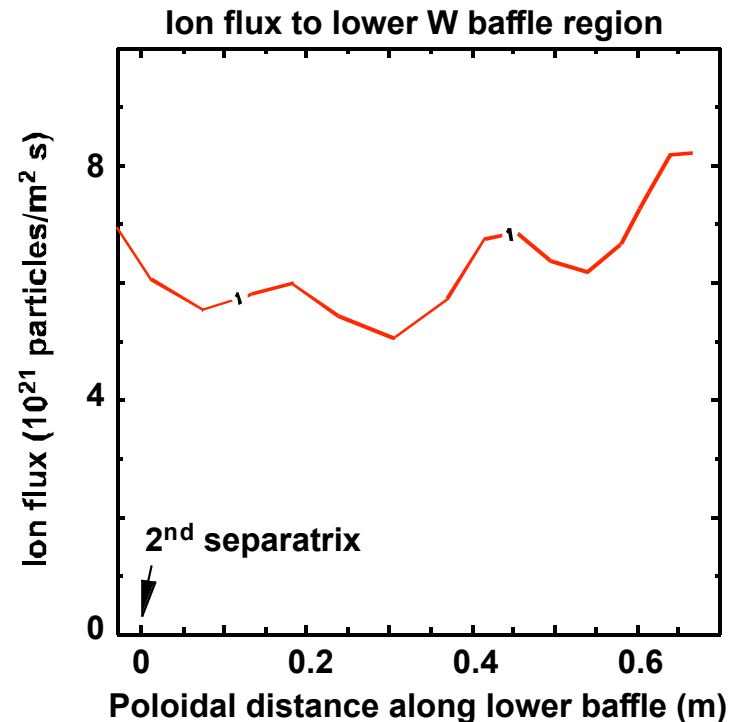
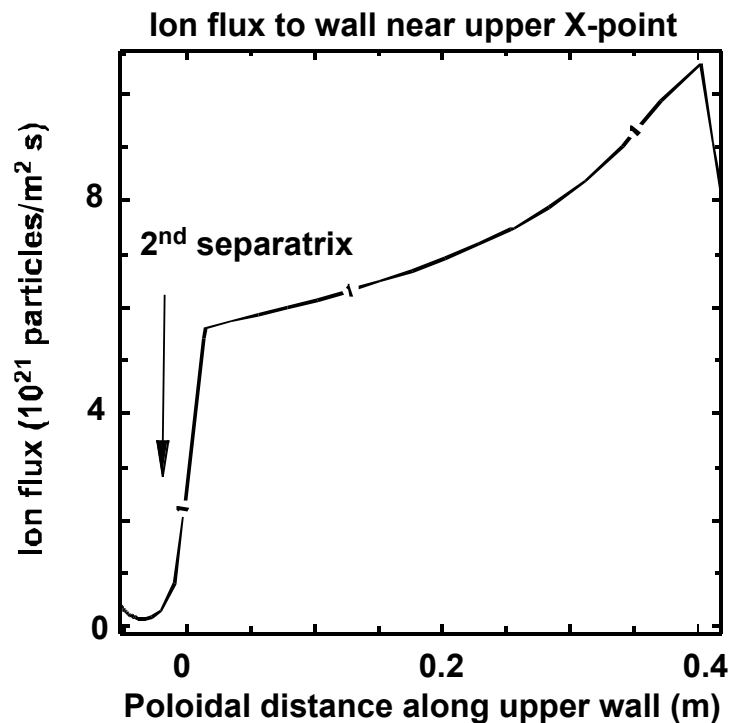
- Inclusion of extended SOL allows us to evaluate wall flux details
- Quantifies “window frame” idea (Lipschultz, Whyte et al.) for ITER



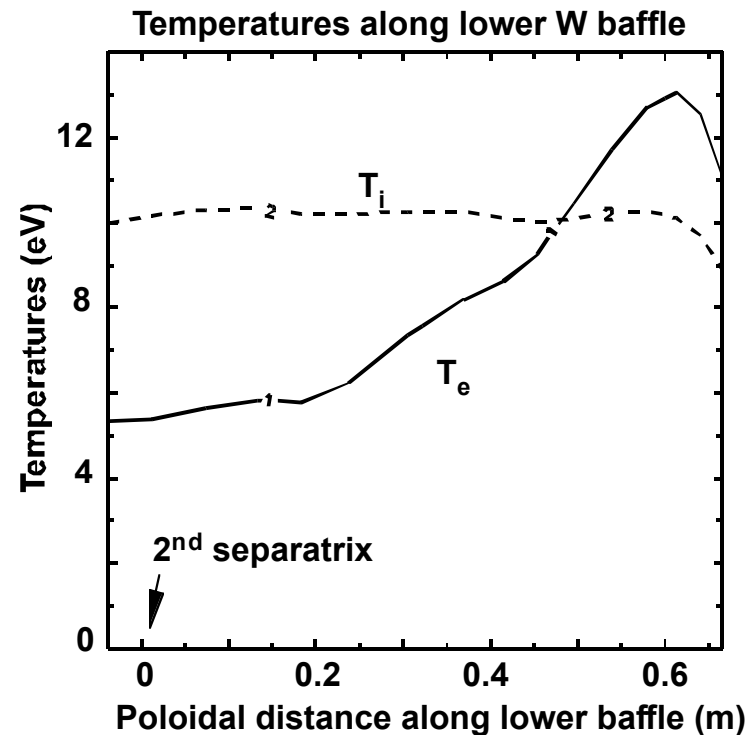
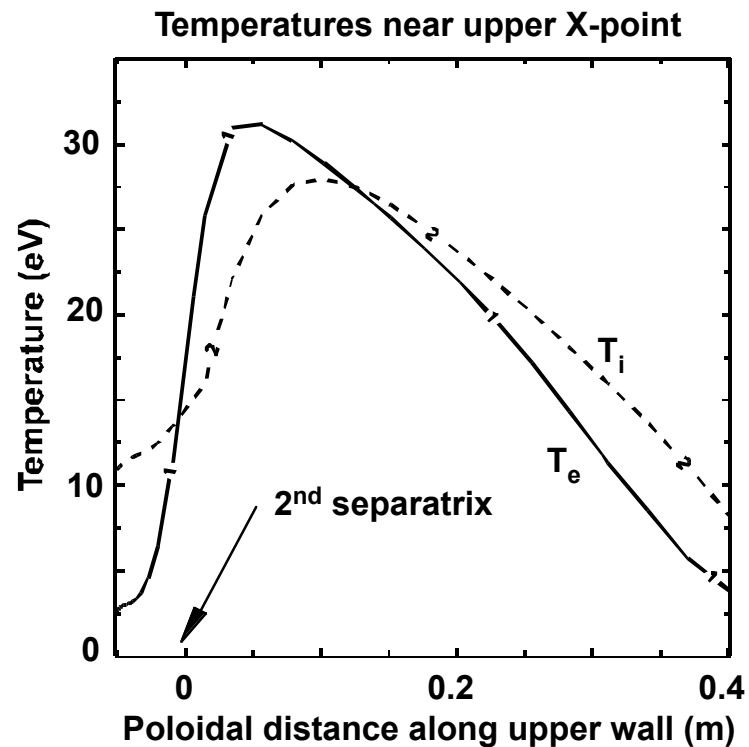
# Extended SOL simulations show large fluxes to upper X-point and W baffle regions



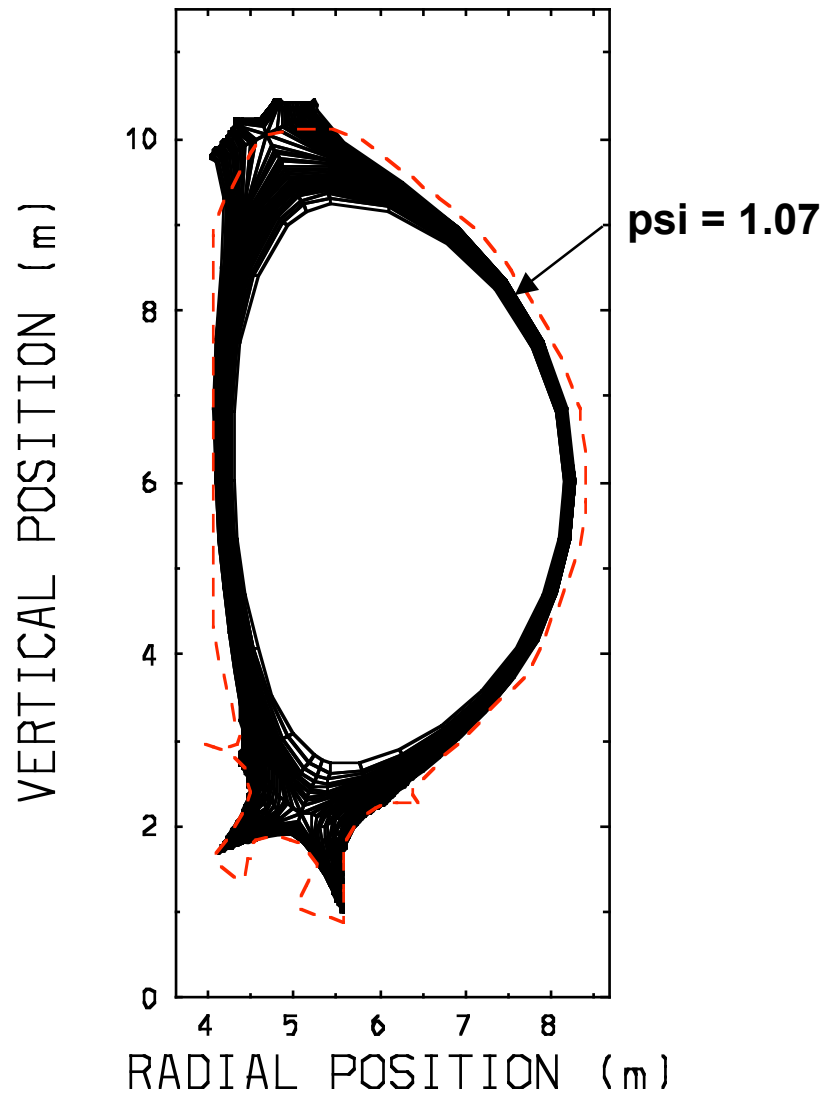
- Comparing  $\psi_{\text{max}} = 1.035$  (SN) to  $\psi_{\text{max}} = 1.07$  (UBDN) shows  $\sim 1/2$  of wall flux concentrates at the upper X-point and W baffle regions
- Such localized fluxes  $\sim 10+$  times the “average” wall flux



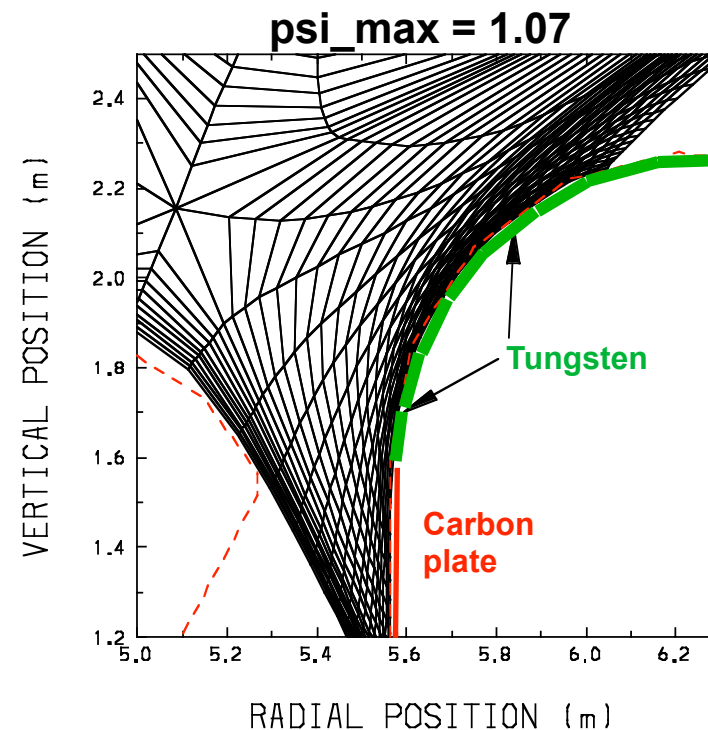
# Temperature profiles shows that upper localized X-point region is hotter than W-baffle region



# Sputtered W (Sn) from the baffle-only provides some backup for WBC result



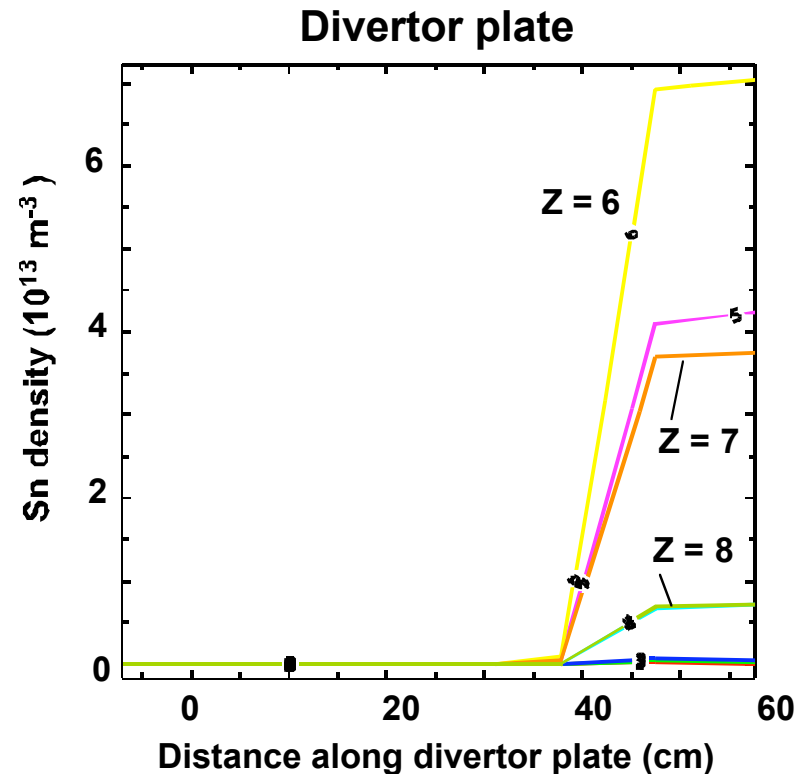
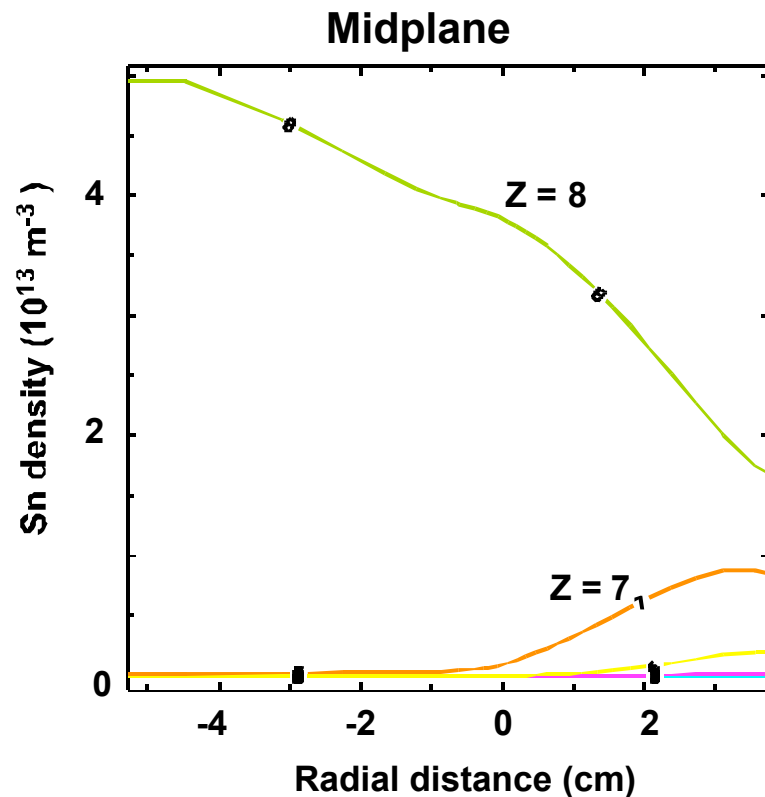
- Very preliminary!
- W sputtering yield is uncertain at lower energies



# Sn is used as a heavy-ion surrogate for W and results in low Sn (W) core concentration



- Yield curve is physical sputtering of W in the baffle region only (estimated)
- Ionization and recombination are taken for Sn (simply available, will be redone with W)
- Location of sputtering is important - midplane worse for impurity intrusion



# Summary and plans



- Be levels at core boundary ~1%; timescale for S.S. is ~1 sec
- CX-sputtering energy spectrum from DEGAS 2 indicates that a high energy tail may be worrisome for W
- Extending simulations to far SOL beyond 2<sup>nd</sup> separatrix quantifies localized fluxes to upper X-point and W-baffle regions
- Surrogate Sn (W) sputtering from baffle may not be a problem as per WBC, but uncertainties are large:
  - upper X-point region not included
  - W sputtering yield at moderate energies
- Ongoing iteration with WBC

# Carbon radiation is localized near the divertor plates; neon would be more diffuse

